Do Jordanian public universities use their resources efficiently? A Data Envelopment Analysis (DEA) of research publications indexed in Scopus*

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Abstract

This study examines the relative technical efficiency of research publications in Jordanian Public Universities (JPUs) using output-oriented Data Envelopment Analysis (DEA) models. By analyzing data for the year 2023, the study incorporates multiple input-output combinations, including faculty and graduates, annual expenditures, research publications, citations, and high-quality publications indexed in Scopus. All universities have witnessed considerable increases in terms of publications indexed in Scopus over the last decade. However, the findings show considerable efficiency disparities across universities, with Jordan University (JU) emerging as the benchmark for high efficiency in most of the models. A noticeable gap in producing research with high quality exists. While some universities demonstrate somehow consistent performance, others particularly those located in remote areas exhibit relatively lower levels of efficiency in most of the models. Based on the findings, there is significant potential for improvement in resource allocation and research quality across various JPUs. This study contributes to the limited body of literature on the efficiency of public resources devoted to higher education in the Jordan. It provides insights for policymakers in the process of efficient resource utilization in public universities.

Keywords: *DEA, Jordan public Universities, Research Quality, Scopus.*

هل تستخدم الجامعات الأردنية الحكومية مواردها بكفاءة؟ تحليل مغلف البيانات (DEA) للنشر العلمي المفهرس في قاعدة بيانات سكوبس

الملخص

تُقيِّم هذه الدراسة الكفاءة الفنية النسبية للمنشورات البحثية في الجامعات الحكومية الأردنية باستخدام نماذج تحليل مغلف البيانات (DEA) الموجهة نحو المخرجات. ومن خلال تحليل بيانات سنة 2023، تتضمن الدراسة العديد من توليفات المدخلات والمخرجات، بما في ذلك عدد أعضاء هيئة التدريس والخريجين، والنفقات السنوية، والمنشورات البحثية، وعدد الاستشهادات، والمنشورات عالية الجودة المفهرسة في قاعدة بيانات سكوبس.

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شهدت جميع الجامعات زيادات ملحوظة في عدد المنشورات المفهرسة في سكوبس خلال العقد الماضي. ومع ذلك، تُظهر النتائج وجود تفاوتات كبيرة في مستويات الكفاءة بين الجامعات، حيث برزت الجامعة الأردنية كمقياس للكفاءة العالية في معظم النماذج. كما لوحظ وجود فجوة واضحة في إنتاج البحوث ذات الجودة العالية في اغلب الجامعات.

وفي حين أظهرت بعض الجامعات أداءً متسقًا إلى حد ما، فإن جامعات أخرى، خصوصًا الواقعة في المناطق النائية، أظهرت مستويات كفاءة أقل نسبيًا في معظم النماذج. واستنادًا إلى النتائج، هناك إمكانية كبيرة لتحسين تخصيص الموارد وجودة البحث في مختلف الجامعات الحكومية الأردنية.

تُسهم هذه الدراسة في سد الفجوة في الأدبيات المحدودة المتعلقة بكفاءة استخدام الموارد العامة المخصصة للتعليم العالي في الأردن، كما تقدم رؤى قيّمة لصنّاع القرار حول سبل الاستخدام الفعّال للموارد في الجامعات الحكومية.

الكلمات المفتاحية: *تحليل مغلف البيانات، الجامعات الحكومية الأردنية، جودة البحث، سكوبس.*

1. Introduction

Resource allocation and technical efficiency analysis lies at the heart of economic analysis of education resources. Technical efficiency is the firm's ability to maximize output from given inputs (Farrell, 1957). This equally extends to the process of public resources utilization within universities which are multi-product organizations that generate various outputs from multiple inputs (Cohn et al., 1989). In addition to knowledge transfer to society and quality teaching, a key indicator of a university's reputation and performance is the volume of high-quality publications and the number of citations on research output carried out by its faculty members.

In Jordan, public higher education institutions, given their financial hardship, face growing local and international competition to attract both domestic and international students while striving to improve their institutional rankings. Over the last decade, the volume of publications produced by the Jordanian Public Universities (JPUs) has increased enormously. This paper applies Data Envelopment Analysis (DEA) method to explore relative technical efficiency of scientific research carried out by JPUs. DEA is a dominant approach in measuring efficiency in higher education institutions, particularly for its multidimensionality (Andersson and Sunds, 2021). It is capable of handling multiple inputs and outputs without requiring a priori statistical assumptions.

This paper contributes to the literature pertaining to efficiency of public higher education institutions in Jordan and the wider Middle East and North Africa (MENA) region where very few attempts have been carried out. To the best knowledge of the

researcher, there has been no previous study examining the efficiency of higher education institutions in Jordan, particularly using DEA. Such analysis guides policymakers in universities in the process of resource allocation and evaluates their efficiency relative to other public higher education institutions. Best-practice universities can serve as benchmarks for other similar institutions fostering competition and contribute to the efficient use of resources in the higher education sector.

The remainder of the paper unfolds as follows. A selective literature review is conducted in the next section, followed by section 3 which summarizes the methodological procedures and data sources. Section 4 shows the results of DEA analysis. The conclusion is presented in the last section.

2. Selective Literature review

There have been several surveys demonstrating scholarly literature of applying DEA in education, economics, and other fields (see Emrouznejad and Yang, 2018) and Johnes, 2015). DEA has been used intensively in university-level studies of efficiency and productivity since mid-1970s (Blecich, 2024). It has become a dominant method for assessing efficiency across universities, departments, faculties, and research institutions (Andersson and Sunds, 2021). Although it employed one input (average college salary), Cohn et al (1989) is one of the early studies that included multiple outputs (undergraduate and graduate students, and scholarships for research) in the non-parametric efficiency analysis. It analyzed data of a group of higher education institutions in the United States. Mainly, the analysis indicated that economies of scale play a significant role regardless of the type of higher education institution (private vs. public). Avkiran (2001) examined efficiencies of thirty-six Australian universities through DEA for the academic year 1995. Mainly, findings from the study showed that the universities were performing well, but there was substantial room for enhancing performance on fee-paying enrollments. Andersson et al. (2016) explored efficiency and productivity for a sample of Swedish universities for the period (2005 to 2008). They indicated that the average inefficiency revolved around 12% and productivity increased by around 1.7% annually. The study concluded that there was some potential for efficiency improvement among the institutions considered. Wolszczak-Derlacz (2014) employed (DEA) to evaluate the relative efficiency of five hundreds higher education institutions from Europe and the United States from 2000

to 2010. The study applied various input-output combinations—including revenue, staff, number of student and graduates, and publications. The findings revealed that in Europe, increased government funding correlates with higher inefficiency. On the other hand, unlike the situation in the U.S, tuition fees appeared to contribute to efficiency in European universities. Blecich (2024) is among the most recent studies that utilized DEA to examine efficiency measures over time and across higher education institutions in Europe. The study incorporates four outputs (graduates, number of overseas students, number of publications and citations) and two inputs (academic staff and public expenditure). The study revealed that efficiency differed by country and period. Inefficiency appeared to result from management underperformance and nonoptimal utilization of the production size. Maral (2024), although it was based on a descriptive analysis, comprehensively reviewed the productivity, impact and quality of research of Turkish higher education from 1980 to 2022 using Web of Science data. The study found that research performance remained below the global average, especially in terms of quality. In Latin American countries, Ramírez-Correa et al. (2012) utilized a DEA model with two input variables [expenses and number of academics) and three output variables (revenue, publications and student enrolments) for a group of Chilean universities. The empirical results showed that only nine out of thirty-four institutions under consideration were efficient at research and teaching levels. In addition, their results revealed insignificant statistical differences, between the efficiency prevailing in public universities vs. private institutions.

In Arab countries, the literature on using non-parametric efficiency analysis of education is rather limited. Srairi (2014) investigated the relative efficiency of eleven Tunisian public universities from 2009 to 2013 using a nonparametric approach. The study assessed efficiency measures over time and compared efficiency based on university size. The results showed a decline in efficiency scores after 2011. Additionally, medium and small universities outperformed larger ones in terms of efficiency. Bouzouita (2019) conducted a similar study on a sample of sixty-two Tunisian higher education institutions in the 2010–2011 academic year. Using DEA, generally the results indicated high efficiency. Many universities operated under decreasing returns to scale, suggesting potential for downsizing. DEA analysis conducted in the later study also identified benchmarks for inefficient institutions, guiding productivity improvements. In Egypt, Mohamed et al (2015) examined the performance of twelve Egyptian universities for the

2010/2011 academic year using DEA models. The study found differences in efficiency levels in the evaluated universities. Inefficiency in some universities arose from operational issues rather than scale, while others faced unfavorable conditions affecting their performance.

The current research aims to contribute to the literature on DEA studies in Arab countries, focusing on the case of (JPUs) for the academic year 2022/2023.

3. Methodology and data sources

3.1 The DEA concept

Principally, the efficiency of higher education production of scientific research can be examined using two fundamental methods: The non-parametric methodology of DEA and the econometric method of stochastic frontiers (SFA), (Salas-Velasco, 2020). The current study utilizes the DEA methodology (Charnes et al., 1978, Banker et al 1984) [(1)],as it allows integrating multiple inputs and outputs in the efficiency analysis (Gralka et al., 2019). Furthermore, unlike the method of stochastic frontiers, DEA requires no distributional assumptions and functional form. The estimation of efficiency using DEA gives robust estimates for

higher education, particularly when the analysis involves several inputs and outputs such as citations and research publications (Villano & Tran, 2021). Although DEA can be used to explore efficiency in any production setting, its initial motivation stemmed from the need to evaluate efficiency in public sector models, where obtaining actual price and cost information has been often challenging. In this regard, the (DEA) has become an essential technique for evaluating efficiency in higher education institutions (Salas-Velasco, 2020). It is a beneficial technique not only for evaluating the efficiency of universities but also for ranking them. The technical and relative efficiency of a group of comparable institutions can be assessed by benchmarking their performance against a best-practice frontier, which represents the highest level of efficiency achieved by the most

(1) Although Farrell (1957) contributed innovatively to the basic ideas and the foundations of DEA, Charnes et al. (1978) developed the modern well-established form of this technique extending its ability to integrate multiple inputs and outputs. Banker et al (1984) is also a seminal work that improved DEA by introducing the so-called BCC model.

effective institutions within the group. This comparison provides valuable insights into the relative performance and highlights areas for improvement in less efficient institutions.

DEA employs mathematical programming to estimate optimal production frontiers and assess the technical and relative efficiencies of various Decision-Making Units (DMUs)(1). It provides efficiency scores as comprehensive measures of individual performance, with DMUs (in this study, universities) achieving a score of 1 being deemed technically efficient. Broadly, efficiency scores indicate how far a DMU is from the best practice frontier, Fried et al (2008).

The Banker-Charnes-Copper output-oriented (BCC) model, (Banker et al 1984) as one of the DEA approaches, is employed in the study. BCC is a variable-returns to scale (VRS) model used to evaluate the relative efficiency of decision-making units (DMUs) while allowing for non-constant returns to scale(2). It is desirable to apply the BCC model in case one is dealing with numerical differences between DMUs, (Cooper et al., 2007). Considering the diverse characteristics of the public universities handled in this research, such as number of graduates, faculty numbers, and expenditure, we apply the BCC model.

3.2 The basic mathematical formulation of DEA(3)

Let a set of ***n*** homogenous Decision-Making Units ***DMUj (j=1,…,n)*** be under evaluation, where each unit utilizes a vector ***m*** of inputs ***(X1j,…,Xmj),*** to generate a vector ***s*** of outputs ***(Y1j,…,Ysj),*** and where ***v*** and ***u*** are input and output vectors of weights of ***DMUj***, respectively. The efficiency of each DMU, fore instance ***k***, is basically the ratio of its weighted output to its weighted inputs.

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(1) The efficiency of a Decision Making Unit (DMU) typically includes two components: technical efficiency (TE) and allocative efficiency (AE). While both measures contribute to total economic efficiency, the current study is solely focused on the measurement of technical efficiency (TE) in JPUs. We can then make comparison of TE across the institutions under investigation.

(2) Returns to scale refers to how the output of a firm changes when the amount of inputs used for production is altered. Under Constant Returns to Scale (CRS), increasing inputs leads to a proportional increase in output. However, CRS may be too restrictive in some cases. Variable Returns to Scale (VRS) is a more flexible approach, accounting for both increasing and decreasing returns to scale. (Charles and Kumar, 2012).

(3) see Cooper et al. (2007) and Charles and Kumar (2012).

$$\boldsymbol{Efficiency\ of\ a\ unit\ under\ considration\ (DMU_k) = \frac{Sum\ of\ Weighted\ outputs\ of\ k}{Sum\ of\ Weighted\ inputs\ of\ k}}$$

Technically, in linear programming procedures developed by the seminal work of Charnes et al. (1978), which assumes constant returns to scale (CRS), the technical efficiency of each DMUs can be found by solving the following maximization objective conditional on certain constraints:

Objective:

$$\boldsymbol{Max\ \theta_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}}$$

Subject to:

$$\boldsymbol{\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1}$$

$$\boldsymbol{\sum_{r=1}^{s} u_r y_{rj} = 1 \quad j = 1, \dots, n}$$

$$\boldsymbol{v_i \geq 0 \quad i = 1, \dots, m}$$

$$\boldsymbol{u_r \geq 0 \quad r = 1, \dots, s}$$

This model through linear programming finds the vectors of weights for inputs and outputs that obtain the maximum efficiency score of a DMU.

Banker et al. (1984) relax the condition that is implied by the previous model and introduced DEA model that enables the assumption of variable returns to scale (VRS). This model is termed in the literature as BCC(1).

3.3 Data considerations

The present study analyzes data from all ten (JPUs), see Table (1). In addition to the number of graduates in the academic year 2022/2023, the study incorporates output variables that are considered to represent scientific research performance of JPUs in 2023. These are Scopus indexed (research publications, high-quality publications, citations, and high-quality journals). The input variables for the same year are (total expenditure, number

(1) See Cooper et al (2007) for more details on technical formulation of the output-oriented BCC model.

of academic staff, and number of employees). Data on input variables were primarily obtained from the official websites of each university. However, some universities did not provide complete data for the targeted year, particularly regarding faculty and employee counts. To address this limitation and based on the assumption that such figures remain relatively stable over short periods, the most recent available data within the 2020–2024 timeframe were used as proxies. Annual expenditure data were sourced from both university websites and official governmental financial reports for the fiscal year 2023.

As shown in Table (1), data on graduates were collected from the annual reports available through the Ministry of Higher Education and Scientific Research's official database. Data related to scientific research was retrieved from the open-access Scopus database. The process of collecting publication data began with a review of each university's Scopus profile to extract the citations and publications. To focus on research quality, we refined our search to include only the top 200 journals in each of Scopus's 27 main subject areas, restricting the selection to journals classified as Q1 or Q2. This filtering process resulted in having a total of 5,175 journals considered to be highly respected ones.

Due to limitations in the availability of open-access institutional-level data on Scopus, extracting information for each university required a manual, time-consuming search of individual university profile pages. For example, regarding the University of Jordan's (JU) profile, we identified 365 journal papers published across 175 high-quality journals, see Table 1.

Table (1):

Descriptive statistics of input and output variables utilized in the DEA analysis (in 2023).

University	Total Expenditure (Million JD)[a]	Employees[b]	Faculty Members[b]	Graduates[c]	Publications[d]	Citations[d]	Publications in High-Quality Journals[d]	Number of High-Quality Journals[d]
Jordan Uni. (**JU**)	116.780	2415	1485	9871	2414	10069	356	175
German Jordan Uni. (**GJU**)	18.470	500	269	725	266	1165	56	44
Hashemite Uni. (**HU**)	51.496	887	865	5130	1200	4878	191	98
Al Al-Bayt Uni. (**AABU**)	32.827	881	440	4233	583	4529	80	49
Al-Balqa Applied Uni. (**BAU**)	83.220	2893	1668	13946	1230	5956	160	77
Al-Hussein Bin Talal Uni. (**AHU**)	23.827	792	363	1849	324	1385	38	24
Tafila Technical Uni. (**TTU**)	17.806	655	246	1676	241	1079	43	25
Jordan Uni. of Science and Technology (**JUST**)	92.221	1940	1068	4350	1665	7468	354	197
Yarmouk Uni. (**YU**)	69.596	1433	1122	7130	1022	4937	111	74
Mutah Uni. (**Mutah**)	56.845	1375	646	4756	662	2358	73	49
Average	**56.309**	**1377.1**	**817.2**	**5366.6**	**960.7**	**4382.4**	**146.2**	**81.2**

a) Rounded amounts obtained from universities' websites and governmental reports

b) Represent the most recent numbers available on a university's website.

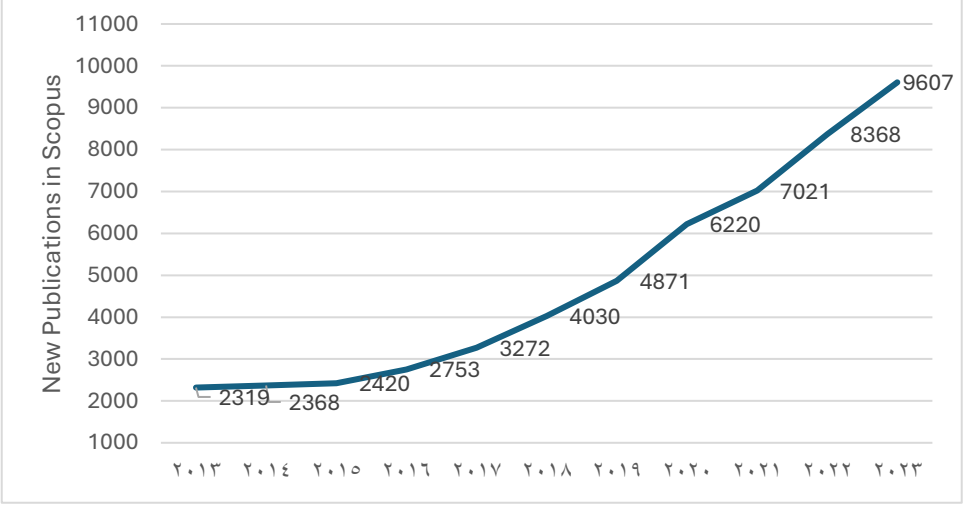
c) Source: Ministry of Higher Education & Scientific Research database

d) Source: Author's calculations based on JPUs' Scopus profiles in 2023.

Figure 1 shows the evolution of scientific publications indexed in Scopus from 2013 to 2023 carried out by faculty members affiliated with (JPUs), regardless of quartile rankings. Over the past decade, there has been an obvious increase in scholarly output, reflecting a heightened recognition of the critical role of knowledge production within universities. This pattern underscores the growing emphasis on research not only as a core mission of universities but also as a significant factor influencing global university rankings.

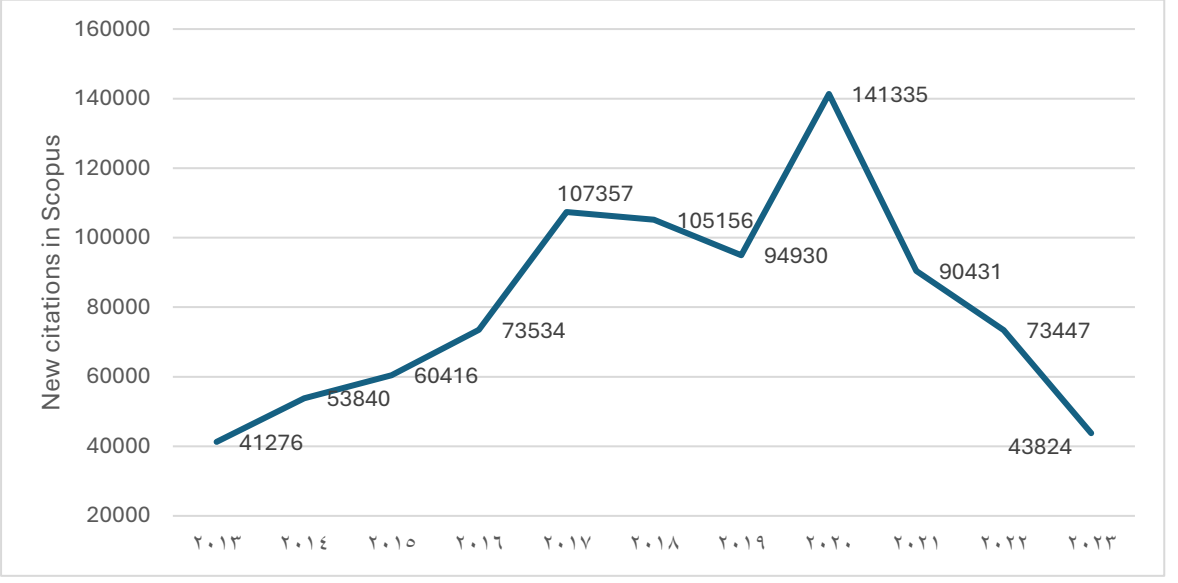
In contrast, although citation activity increased during the period from 2013 to 2020, the total number of new citations for previously published scientific work affiliated with (JPUs) has declined noticeably over the past three years (2021–2023), as illustrated in Figure (2). One plausible explanation is the escalating global competition among researchers to publish in high-impact or Scopus-indexed journals, which tends to favor institutions with stronger research infrastructures and broader international visibility (Bornmann & Haunschild, 2018). Additionally, current academic promotion regulations in some Jordanian public universities may still recognize publications of limited scope and quality, which may not attract significant international citations. Furthermore, the recent rise in financial constraints and the persistent underfunding of scientific research are likely to contribute to this trend by limiting the ability of local researchers to engage in internationally co-authored projects and access high-quality research platforms.

Figure 1: Annual Scientific Publications from Jordanian Public Universities Indexed in Scopus (2013–2023)



Source: Author's calculations based on JPUs' Scopus profiles in 2023.

Figure 2: Annual Citations on Scientific Publications form Jordanian Public Universities Indexed in Scopus (2013–2023)



Source: Author's calculations based on JPUs' Scopus profiles in 2023.

4. Results of DEA analysis

According to DEA, a DMU is fully efficient if its efficiency scores equal to one, with no slack in either outputs or inputs. Fully efficient cases are (abbreviated as ***E*** in the analysis below). If the efficiency score is less than one, it is considered inefficient (abbreviated as ***I.E*** in the analysis below). Additionally, if the score is one coupled with a slack in either the outputs or inputs, the DMU is regarded as weakly efficient, (abbreviated as ***W.E*** in the analysis below), (Zhu, 2000; Charles and Kumar, 2012).

4.1 Models with one input vs one output

We start the analysis by introducing models that present a simple analysis of the efficiency in JPUs. The models incorporate only one input (number of faculty members) and one output representing scientific research dimensions (i.e. number of publications, citations or number of quality publications). Table (2) demonstrates that the average efficiency (Technical efficiency) of the public universities varies by output variable. With respect to the quantity of publications that were published in 2023 the average efficiency amounts to 0.835 declining to 0.650 and 0.633 in terms of the number of citations and high-quality publications, respectively. JU represents a consistent benchmark for other

universities across the three models in this simple analysis. The value of efficiency differs across the ten universities as well. As whole, such average and per university efficiency scores will differ when we make our analysis more realistic by incorporating multiple inputs and outputs (see Tables 3 and 4).

Table 2:

DEA Efficiency Scores VRS models (one input: number of faculty members)*

DMU (University)	Model 1 Output= number of publications			Model 2 Output=number of citations			Model 3 Output=number of high-quality publications		
	Rank	*Effci. Scores*	*Effci. Level*	*Rank*	*Effci. Scores*	*Effci. Level*	*Rank*	*Effci. Scores*	*Effci. Level*
JU	1	1.000	E	1	1	E	1	1	E
GJU	5	0.945	I.E	8	0.421	I.E	3	1	W.E
HU	6	0.904	I.E	4	0.719	I.E	4	0.686	I.E
AABU	2	1.000	W.E	1	1	E	5	0.668	I.E
BAU	10	0.510	I.E	6	0.592	I.E	7	0.449	I.E
AHU	7	0.724	I.E	10	0.371	I.E	9	0.316	I.E
TTU	3	1.000	W.E	7	0.426	I.E	6	0.527	I.E
JUST	4	0.989	I.E	3	0.950	I.E	1	1	E
YU	9	0.575	I.E	5	0.606	I.E	10	0.313	I.E
Mutah	8	0.701	I.E	9	0.419	I.E	8	0.371	I.E
Average	**0.835 (SD: 0.190)**			**0.650 (SD:0.253)**			**0.633 (SD: 0.283)**		

SD: Standard Deviation, E: Efficient, I.E: Inefficient, W.E: Weakly Efficient, Effci.: Efficiency.

*** Utilizing the (dea) command available in STATA 17**

4.2 Models with multiple inputs vs one output

Table 3 shows the results of DEA analysis using all input variables (i.e. number of faculty members, number of employees and total expenditure) across four models, inserting a different output for each model. Model 4 reports the efficiency of the public universities with respect to publications indexed in Scopus in 2023, regardless of quartile rankings. Models 5 through 7 replicate the same analytical procedure, focusing respectively on: (1) the number of Scopus-indexed citations, (2) the number of Scopus-indexed high-quality publications, and (3) the number of Scopus-indexed high-quality journals in which these high-quality publications by JPUs-affiliated authors appear.

Overall, the results in Table 3 disclose interesting patterns. In the context of the models 4 through 6, JU (Jordan University) consistently demonstrates high efficiency in all three models, making it the most efficient university in terms of publications, citations, and high-quality publications. On the other hand, GJU (German Jordanian University) shows mixed performance. This suggests GJU has a strong performance in publications and quality publications but struggles with citations. HU (Hashemite University) shows excellent performance, being efficient across all three models, indicating consistency in publications, citations, and quality publications. JUST (Jordan University of Science and Technology) is relatively strong in publications, but weaker in citations, and exhibits efficiency in quality publications. AABU (Al Al-Bayt University) demonstrates inconsistent results indicating weaknesses in producing high-quality publications despite good overall performance in publications and citations.

Table 3:

DEA Efficiency Scores VRS models (Three inputs: number of faculty members, number of employees and total expenditure)*

DMU (University)	Model 4 Output= number of publications			Model 5 Output=number of citations			Model 6 Output= number of high-quality publications			Model 7 Output= number of high-quality journals		
	Rank	*Effci. Scores*	*Effci. Level*	*Rank*	*Effci. Scores*	*Effci. Level*	*Rank*	*Effci. Scores*	*Effci. Level*	*Rank*	*Effci. Scores*	*Effci. Level*
JU	1	1.000	E	1	1.000	E	1	1.000	E	4	0.888	I.E
GJU	3	1.000	W.E	7	0.457	I.E	4	1.000	W.E	1	1.000	E
HU	1	1.000	E	1	1.000	E	1	1.000	E	1	1.000	E
AABU	5	1.000	W.E	1	1.000	E	6	0.701	I.E	5	0.664	E
BAU	9	0.687	I.E	5	0.758	I.E	7	0.503	I.E	9	0.432	I.E
AHU	7	0.779	I.E	9	0.421	I.E	8	0.488	I.E	8	0.436	I.E
TTU	4	1.000	W.E	8	0.439	I.E	5	0.747	I.E	6	0.621	I.E
JUST	6	0.989	I.E	4	0.950	I.E	1	1.000	E	1	1.000	E
YU	10	0.665	I.E	6	0.744	I.E	9	0.421	I.E	7	0.505	I.E
Mutah	8	0.701	I.E	10	0.419	I.E	10	0.371	I.E	10	0.422	I.E
Average	**0.882 (SD: 0.152)**			**0.719 (SD: 0.262)**			**0.723 (SD: 0.263)**			**0.697 (SD:0.252)**		

SD: Standard Deviation, E: Efficient, I.E: Inefficient, W.E: Weakly Efficient, Effci.: Efficiency.

*** Utilizing the (dea) command available in STATA 17.**

This, somehow, applies for TTU (Tafila Technical University) which shows mixed performance. The other four universities AHU (Al-Hussein Bin Talal University), BAU (Al-Balqa Applied University), Mutah (Mutah University) and YU (Yarmouk University) are inefficient across most of the models, indicating significant room for improvement. Model 7 in Table 3 presents the results of the DEA efficiency assessment, focusing on the output variable representing the number of Scopus-indexed high-quality journals in which publications by JPUs-affiliated authors appear. The analysis identifies GJU, HU, and JUST as the most efficient institutions, setting a performance benchmark for the remaining universities. JU emerges as the institution most comparable to these leading performers. In contrast, the remaining six universities demonstrate clear inefficiencies in this context and require substantial improvements to reach comparable levels of performance.

Examining patterns of the average efficiency scores reveals that (JPUs) are relatively at a better place in the number of publications produced compared with the other three outputs that better reflect the quality of scientific research. The standard deviation is also much smaller in the case of model 4, suggesting a smaller difference among the universities compared to the deviation in the other three models reported in Table (3).

4.3 Models with multiple inputs and multiple outputs

The analysis presented in Table 4 illustrates efficiency patterns of (JPUs) under two DEA models: model 8, which uses publications, citations, and graduates as output variables, and Model 9, which considers quality publications and high-quality journals. Both models share the same input variables—faculty members, employees, and total expenditure. By incorporating multiple outputs, these models are likely to provide a more accurate representation of the technical and relative efficiency of higher education institutions in Jordan. Compared to the analysis in Table 3, the results in Table 4 show substantial differences, particularly in model 8, which includes three fundamental outputs that reflect the core missions of universities. On the other hand, model 9 represents the quality side of educational production by focusing on quality publications and quality journals.

Table 4:

DEA Efficiency Scores VRS models (Three inputs: number of faculty members, number of employees and total expenditure*

DMU (University)	Model 8 Output=numbers of Publications, citations and graduates			Model 9 Output=numbers of quality publications and quality journals		
	Rank	Effci. Scores	Effci. Level	Rank	Effci. Scores	Effci. Level
JU	1	1.000	E	1	1.000	E
GJU	6	1.000	W.E	1	1.000	E
HU	1	1.000	E	1	1.000	E
AABU	4	1.000	W.E	6	0.701	I.E
BAU	1	1.000	E	8	0.503	I.E
AHU	10	0.792	I.E	9	0.488	I.E
TTU	5	1.000	W.E	5	0.747	I.E
JUST	7	0.989	I.E	1	1.000	E
YU	8	0.949	I.E	7	0.505	I.E
Mutah	9	0.840	I.E	10	0.422	I.E
Average	**0.957 (SD: 0.0768)**			**0.737 (SD: 0.247)**		

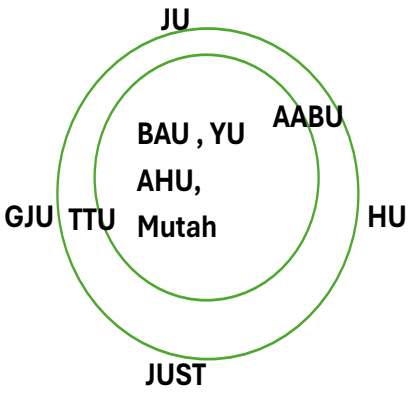
SD: Standard Deviation, E: Efficient, I.E: Inefficient, W.E: Weakly Efficient, Effci.: Efficiency. * Utilizing the (dea) command available in STATA 17.

Model 8 demonstrates a higher average efficiency score of 0.957 with less variation among universities, compared to Model 9 and the previously reported models. In contrast, Model 9, which emphasizes quality-focused outputs, records a lower average efficiency score of 0.737 and a higher standard deviation (SD = 0.247), indicating greater variability and reduced efficiency across institutions when quality metrics are considered. These results suggest that universities tend to perform more efficiently when assessed using quantity-based output (model 8) rather than quality-based measures (model 9).

Many universities scored (1) in model 8, implying strong performance when considering broad outcomes such as number of graduates or students. The most efficient universities in this regard are JU, HU, BAU, followed by GJU and TTU (weakly efficient). JUST's and YU's efficiency is very close to full efficiency level. The last two universities (AHU and Mutah) lie around 20% away from the best universities in terms of quantity-based outputs.

JU, GJU and HU are efficient under both models, suggesting consistent excellence in both quantity and quality. JUST significantly ranks 1 in Model 9 despite being slightly inefficient in Model 8. This indicates its strength in quality research outputs. An interesting observation is that BAU is efficient in Model 8 but drops sharply in Model 9 (score: 0.503), highlighting a gap in quality research outputs. This pattern partially applies to the other three universities (AABU, YU and TTU). The remaining two universities (AHU and Mutah) rank lowest in model 9, like their performance in Model 8, implying efficiency gaps in all aspects of teaching and research. In general, universities that may appear efficient in terms of quantity academic outputs may not necessarily be performing well when research quality is considered.

Figure 3: JPUs' efficiency levels in research quality in 2023 as depicted in model 9



Focusing on quality, when JPUs are judged on quality-oriented research, six out of ten universities are found to be inefficient compared to the best practice taking place within the other institutions. Figure (3) demonstrates JPUs' efficiency levels in research quality (number of quality articles and quality journals) in 2023. Universities of JU, GJU, HU, JUST, which lie on the outer circle are efficient. The outer circle is a simple presentation of the production frontier which represents the locus of maximum production of a certain output using the available inputs. Those universities located inside the inner circle are considerably inefficient. The other two universities (AABU and TTU), which are located on the inner circle, are slightly inefficient. The latter two universities are much closer to the efficient universities than (BAU, YU, AHU, and Mutah).

5. Conclusion

By utilizing Data Envelopment Analysis (DEA), the current employs various input-output combinations to examine to what extent Jordanian Public Universities (JPUs) are efficient in utilizing their resources, focusing on producing scientific research. Primarily, the analysis is based on publication data indexed in Scopus for the year 2023. The study on the efficiency provides valuable insights into JPUs' research output and performance. Best-practice universities can serve as benchmarks for other similar institutions fostering competition and contribute to the efficient use of resources in the higher education sector.

The main findings of the study reveal that efficiency levels vary across the evaluated universities. Noticeably, while some universities show high relative technical efficiency in terms of publications, there is considerable variability in their efficiency when considering the quality of research. Jordan University (JU) stands out as a consistent performer across the various models designed, setting the standard for other institutions. On the other hand, universities like AHU, Mutah, and YU exhibit persistent lower levels of efficiency, particularly in producing high-quality publications and getting citations on their research.

The findings suggest that JPUs must concentrate not only on increasing the quantity of publications but also on improving the quality of their research to augment their international reputation and impact. Additionally, strengthening international collaborations, improving funding for research activities, and enhancing faculty development programs are essential steps for bridging the performance gaps observed. Future research could explore the reasons behind inefficiencies in specific universities and propose tailored strategies to improve their research productivity and quality. Furthermore, researchers in this field are advised to integrate private higher education institutions in efficiency investigation.

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